Topic 1g - Part 1: Satellite measurements - Measuring the absorption of light in the atmosphere

[MUSIC PLAYING] Atmospheric monitoring has come along a huge amount in the past few years. So just take us through a little bit where it came from and where it's going next. What's the trajectory that we're on?

Right from the earliest days of intellectual science, people wanted to measure what happened to light and how that changed the world in which we live-- how they looked at that world. And it was a discovery of how we look to the world that I think made people look upwards into the atmosphere and look at the sun's light coming through and realized that it wasn't what they thought it would be. Eventually, we discovered ozone. We discovered other molecules in the atmosphere.

And those measurements were very localized. Looking upwards, getting a nice, sophisticated spectrometer for those days, and being able to measure sunlight as a function of wavelength and to look at the variations that enable us to make discoveries about the atmosphere.

So what we're talking about here is that we can split sunlight, for example, into a rainbow. But if you look very carefully at that rainbow, there are some bits that are missing, or there's less of them. And that's not just the visible spectrum but beyond that as well.

Absolutely. Absolutely. The first work was really the visible because that was the obvious place to look. But actually, it turns out that the infrared is as interesting and as complex as that visible spectrum. And it has the signatures of many of the gases that everyone knows today-- carbon dioxide, water vapour. We all understand it has something to do with greenhouse gas effect. And it's that infrared part of the spectrum that controls it.

So the key thing was can we get these instruments into space? Start of the space age in the 50s, it wasn't so long after that people started to build the first instruments. So by the 70s, you already had instruments in space that could look at those wavelengths and select particular wavelength and use those to start to measure concentrations in the atmosphere not just above our heads today but further apart-- across the globe-- which we'd never been able to do before.

It's interesting to study what's there by studying what's missing, which is what you're talking about. You've got instruments down here on the ground. And then as soon as you go up above the atmosphere, you can look at what's arriving. And you can see the difference between the top and the bottom. And it's a subtle thing, isn't it? But there's so much information in that.

There is. There is. And it's actually interesting that technology-wise, we actually had to do a kind of circuitous route. So the spectrometers you could put on the ground looking upwards could see lots of variations with wavelength. But we couldn't fly them in space.

It was too expensive. It's too complicated. They probably wouldn't work. So we had simpler-- perhaps more accurate instruments, but simpler-- that were targeted to particular molecules.

Now, the latest generation of satellite instruments are back to flying those ground spectrometers but in space-- and, in fact, ever more impressive instruments. I always say to my chemist friends that the instruments we fly in space now are 40 times more powerful, in terms of resolving those wavelengths, than the instruments they use in their laboratories.

I bet that makes you popular.

It makes me proud. These are complicated instruments to fly in space. And they have moving parts, which, traditionally, the space industry is very worried about because that increases the rate of failure. But they've had very good histories. And to give you one idea, when we launched the first of these thermal infrared instruments, we expected to measure well about six to eight chemical species.

Well, at least, the space agencies were confident about that. As scientists, I think we dreamt that there would be more. And we almost knew there would be more. But one of those instruments, MIPAS, which measures atmospheric constituents by passive sounding, measured up to 40 species globally in its time in operation.

So this is like a chemist's dream. There's no test tubes and chemical reactions to work out what's there. You've just got single instruments.

Yes, and this is your natural laboratory in space. This is where you can study chemistry reactions as they really happen. Otherwise, we have to study them reaction by reaction or build a chamber. And it's different on every place on the earth. So you can study them together, and you can study them in detail.

We use the instruments to look at the sun and then to look at the changes of the solar spectrum between reaching the earth and coming back from the earth's surface. And that we do in several instruments here, SCIAMACHY is one of them. And using these changes, we can measure absorptions, which are like fingerprints of the gases in the atmosphere.

We can also measure scattering properties, which give us information about the aerosols. And we interpret-- so we sit here and basically making a measurement of the sun above the atmosphere and then look down or look through the atmosphere and look at how the sun's spectrum has been changed.

So what we're talking about here is if you imagine looking at the rainbow, for example, a full rainbow goes in. And what comes out has dark lines. It's got bits missing.

It's got bits missing. And it's changed in the colour. And the changes of the colour are unique to the gases, just like our eyes are kind of unique to people. The absorptions of the gases are unique.

So we use those to determine gases. And then we use other physical principles or laws to determine the aerosol scattering or the surface phenomena. Also, the surface absorbs. So we have this mixture of absorptions and scattering effects.

And we have to do what's called deconvolve that, which means we separate it into its components. But they're like waves, or they have characteristic structure. That's a better way of looking at it.

And that's what we can do. When we get the data down to the ground and into the computer, we can do that. And we can do that, as it turns out, very rapidly. And using this, we're trying to get two or three dimensional pictures of the amounts and distributions of the gases and scattering components like aerosols and like clouds.

So basically, your satellite sitting up here on its platform looking down at the earth is usually measuring, basically, radiation. It's measuring the electromagnetic spectrum.

So that's light.

That's light. And you choose which bit you want to measure. So, basically, depending on the part of the spectrum, you might see different features, you might see different trace gases. So in our community-- in the atmospheric composition community-- actually, we can use quite a lot. We can use data right from the UV visible running right through the infrared.

So it's moving in wavelengths, even out to the millimeter wave and the microwave. So when you hear about ozone, that's done in the UV visible.

We see the colours of the rainbow. And the atmosphere is pretty much transparent in those colours. But actually, that is not true for colours outside that range. And that's what the satellites use, isn't it?

What they use is the interaction between the molecules in the atmosphere or the particles in the atmosphere with the radiation. So there's a couple of things they can do. They can scatter radiation. So they can change the direction so that you measure it in a different place at the satellite.

They can absorb radiation. And when you're in the infrared, you also get re-emission. They can emit radiation. So you need to know how these different little particles or molecules behave when it interacts with light. And you can use that to infer what you're seeing at the satellite.

So often, we talk about the absorption spectra of a molecule. So then you can say, OK, it's absorbed this much, it's scattered that much. Therefore, there must be that much of it down there. I mean that's a little bit of a simplification, but in the end, that's what you're doing.

You have a light source, and that can be the sun. Or it can be the satellite. And then light goes on a journey, and it's changed on the journey. But when it passes through, and then you get the answer to the puzzle. But you have to work out what the question was.

It's like any kind of remote sensing. What you're basically doing is a change to your source, which, typically, for us, is either solar radiation, which is then scattered back to the satellite, or it could be emitted radiation-- so in the thermal infrared. And you're just inferring changes to it.

It's a remote sensing technique that you'll see in a medical laboratory. They put a signal in, and they take a look at you, and by the changes, they infer what's going on. So it's very similar.

It's just, we typically use high spectral resolution information. We use spectra with lots of little features to try and find out what's in there because many times, the influences of different gases will overlay one another. So you have to pick parts of the spectrum where you can isolate what you want to know, where you can remove other effects and then get your final product.

Fundamentally, there is information. And our eyes can only see so much of that information. But a satellite-- different types of satellites-- can pick out different-- they can see different things. All of the stuff is there anyway. You have to know where to look.

That's right. You have to, first of all, choose your problem, decide what you want to look at, and then knowing what its characteristics are. You design your instrument just to look at that particular part of the light, let's call it. So it's looking for what you want to see.

It's really specifically designed to look for what you want to see. You don't kind of look blindly. You say, OK, I know that it should interact like this-- my little molecule. So I designed my instrument to see those kind of changes. And that's what we're doing all the time.

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